BELLCOMM, INC.

SUBJECT: Cabin Atmosphere in the AAP Cluster Spacecraft Case 600-3

DATE: February 17, 1967

FROM: D. J. Belz

ABSTRACT

Mercury, Gemini, and Apollo spacecraft have been designed to provide a pure oxygen atmosphere at a pressure of 5 psia. A departure from that atmosphere in the AAP Cluster is under consideration for two reasons: to prevent possibly harmful physiological effects on crew members during extended mission durations and to reduce the fire hazard associated with a pure oxygen environment. The duration of the AAP 3/4 mission (56 days) exceeds by nearly a factor of 2 the maximum duration in which humans have been exposed to pure oxygen at 5 psia. NASA/MM has recommended a 69% oxygen, 31% nitrogen atmosphere at a total pressure of 5 psia for the Workshop, assuming the CM ECS is retained without modification.

Experiments performed in attempts to simulate the effects of meteoroid penetrations have indicated a potential fire hazard due to such penetrations in a pure oxygen environment. The addition of a fire retardant lining and/or external meteoroid bumper has been proposed to alleviate that hazard.

Although no physiological requirement exists for a two-gas atmosphere on the AAP 1/2 mission, it may be desirable to provide one to allow a 28-day operational test of the two-gas ECS before relying on it for 56 days during AAP 3/4. Quantities of nitrogen and associated tankage required to support two-gas operations during AAP 3/4 alone and during both AAP 1/2 and 3/4 are shown in accompanying tables.

(NASA-CR-153702) CABIN ATMOSPHERE IN THE AAP CLUSTER SPACECRAFT (Bellcomm, Inc.) 10 p

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MEMORANDUM FOR FILE

INTRODUCTION

The major parameters that define a nominal spacecraft cabin atmosphere are temperature and chemical composition, and the partial pressures of each gaseous component.

Mercury, Gemini, and Apollo spacecraft have been designed to provide a pure oxygen atmosphere at a pressure of 5 psia. A departure from that atmosphere in the Cluster is being considered for two reasons: (1) to prevent possibly harmful physiological effects on crew members during extended mission durations, and (2) to reduce the fire hazard associated with a pure oxygen environment.

Physiological Requirements and System Implications

The physiological safety of a 5 psia pure O_2 atmosphere is strongly dependent on mission duration. Exposures of humans to pure oxygen at 5 psia have been experienced in orbital flight for durations up to 13.8 days (Gemini 7) and in ground simulation tests for durations up to 30 days. The physiological response of test subjects to such exposures has not been consistent - symptoms such as aural and possibly pulmonary atelectasis, mucous membrane irritation, slight reductions in hematocrit, and possible changes in renal (kidney) function have, however, been reported in some cases (References 1-3); in no case were such symptoms of such severity as to interfere with the normal completion of a space mission. A planned 56-day mission for the crew of AAP-3 in conjunction with the Cluster, however, exceeds by nearly a factor of 2 the longest exposure (30 days) to pure oxygen at 5 psia yet experienced by human subjects. In the absence of simulations exposing humans to such an atmosphere, a conservative approach strongly suggests the use of a spacecraft environment more nearly representative of the Earth's atmosphere in conjunction with ground simulations employing the atmosphere selected.

A two-gas environment composed of oxygen and nitrogen has been proposed by NASA/MM (Reference 4). A total pressure of 5 psia (69% O_2, 31% N_2) is favored for the following reasons:

1. It is desirable to have equal cabin pressures in each spacecraft module of the Cluster to reduce operational restrictions on crew transfers between modules.

2. To accommodate nominal cabin pressures appreciably higher than 5 psia would require structural modifications of the LM/ATM crew compartment to contain the increased pressure and might require a similar structural modification or re-qualification testing of the CM pressure hull.

3. Depressurization from an O_2 - N_2 cabin atmosphere to a pure oxygen spacesuit atmosphere (3.7 to 3.9 psia) during normal or emergency operations incurs an increasing risk of dysbarism (decompression sickness) as the pressure differential between suit and cabin increases.*

An experimental exposure of four human test subjects to a 68.2% oxygen, 28.7% helium atmosphere at a total pressure of 5 psia for 56 days indicated that at no time were there any clinical disturbances that might have prevented the completion of a space mission (References 5-9). The writer is not aware of any comparable tests conducted to date using nitrogen as an inert atmospheric diluent.

Fire Hazard Due to Meteoroid Penetration of the Workshop

In addition to physiological considerations, the possibility of a conflagration in an oxygen-rich or "pure" oxygen atmosphere has been a source of concern for some time. Potential mechanisms for the ignition of fire include electrostatic sparks, contact with hot surfaces, and meteoroid penetrations.

Attempts have been made to simulate the fire hazard associated with meteoroid pentrations. Studies conducted at the Ling-Temco Vought Company included bombardment of test chambers (0.07" aluminum walls) with aluminum particles ∿ 10 microns in diameter at speeds up to 20 Km/sec. Impact resulted in local melting and vaporization of the chamber wall; penetration of the wall introduced molten and vaporized aluminum into the test chamber within which explosive oxidation occurred in

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*Less than 1% of an astronaut population would be expected to experience symptoms of decompression sickness for a cabin pressure of 5 psia (Reference 4).

[redacted]

flashes extending up to 8 inches from the wall. The peak flash intensity varied with the chemical composition of the atmosphere within the chamber: for a standard atmospheric composition at sea level pressure, flash intensity was reported as only 15% of the intensity for a pure oxygen atmosphere at 5 psia (Reference 10).

Tests conducted by MSFC have shown that coupons of the polyurethane foam insulation used to line the S-IVB hydrogen tank (Orbital Workshop) will burn in a 5 psia oxygen environment when struck with a 1/8" diameter aluminum pellet at speeds between 17,000 and 27,000 ft/sec. (Reference 11). The probability of a meteoroid penetration of the S-IVB Workshop during a 28-day mission has been estimated to be 0.0077.* If a penetration is assumed to be a catastrophic event due to fire hazard, the Apollo goal of no more than a 0.01** probability meteoroid hazard is not met for missions exceeding 36.3 days. Therefore, with regard to the fire hazard resulting from a meteoroid penetration, the Apollo reliability goal is met by the Workshop for AAP 1/2 but is not met for AAP 3/4.

Two solutions to the possible problem of a fire hazard resulting from a meteoroid penetration have been considered:

1. Add a fire-retardant coating to the present S-IVB LH_2 tank interior wall to reduce or eliminate the fire hazard in the event of a meteoroid penetration (Reference 11).

2. Add a meteoroid bumper to the Workshop to reduce the probability of a penetration to an acceptable level for planned mission durations (Reference 11).

The alternatives of providing a fire-retardant lining or a meteoroid shield for the Workshop have been explored by MSFC. Tests of simulated S-IVB LH_2 tank walls coated with KAPTON, Dynatherm-65, and aluminum foil have been conducted to determine their degree of effectiveness as fire-retardants in the event of a meteoroid penetration. Each coating has, however, indicated some degree of combustibility. Assuming the validity of meteoroid penetration probabilities quoted

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*Based on Reference 12.

**Reference 13, Section 3.1.3.3.2.

above, the alternative of a meteoroid shield appears to offer more assurance against fire induced by meteoroid penetrations than an internal fire retardant coating.* Assuming that weight margins on AAP-2 permit the installation of a meteoroid bumper, the fire hazard due to penetrations can be kept within the reliability goals of the Apollo spacecraft.

As discussed above, potential fire-ignition mechanisms such as electrostatic sparks or abnormally hot surfaces may occur in addition to meteoroid penetrations. Since any atmosphere capable of supporting human life will support combustion to some degree, the fire hazard on manned spacecraft cannot be eliminated completely. It can, however, be minimized by careful selection of materials and rigorous ground testing of spacecraft systems and the spacecraft itself.

<u>ECS Hardware Modification and Consumables</u>

During AAP 3/4, three independent environmental control systems will be operating within the Cluster. Without modification, the LM and CM ECS's will maintain a nominal total pressure of 5 psia within their respective crew compartments by supplying oxygen or venting cabin atmospheres overboard. To avoid modification of those environmental control systems it has been proposed to supply nitrogen and maintain required partial pressures using the Airlock Module ECS.

The Airlock Module under design since April 1966 employs a modified Gemini ECS to supply pure oxygen and to maintain a total cabin pressure of 5 psia (References 14-15). A so-called "nitrogen overlay" added to this ECS could provide nitrogen directly to the Airlock Module, Multiple Docking Adapter and Workshop. Oxygen partial pressure sensors and controls added to the ECS would then monitor and maintain the PO_2.

Although the CM and LM/ATM environmental control systems are one-gas systems, crew transfers between modules will introduce nitrogen throughout all pressurized components of the Cluster. This will occur whether or not the MDA/CM and MDA/LM-ATM hatches are normally closed or normally open. If equal cabin pressures are used throughout the Cluster, the partial pressure of Nitrogen (PN_2) will not exceed the PN_2 in the AM/Workshop/MDA.

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*Spalled particles resulting from a meteoroid impact are expected to be "cold" fragments that will not create a direct fire hazard. They may, however, cause impact injuries to crew members. The probability of "spalling" impacts against the Workshop is .038 for a 28-day mission and 0.077 for a 56-day mission (Reference 12). These relatively high probabilities are an added incentive to provide a meteoroid bumper for the workshop.

Two different approaches to controlling the partial pressures of oxygen and nitrogen have been proposed. The first would employ manual monitoring and control of the O_2 partial pressure. The second relies on continuous automatic monitoring and control with an appropriate warning device in case of malfunction and provision for a manual override of the automatic system. Use of the manual system implies periodic replenishment ($\sim$ once per day) of nitrogen in the atmosphere to replace losses due to leakage.

Nitrogen is not consumed metabolically: therefore N_2 requirements derive solely from initial pressurization requirements and leakage. McDonnell* has estimated that 578 lbs of N_2 would be required during AAP 3/4 (see Table 1). Although no physiological requirement exists for a two-gas atmosphere on AAP 1/2, it may be desirable to provide one to allow a 28-day operational test of the two-gas ECS before relying on it for 56 days during AAP 3/4. If a two-gas atmosphere is used during both AAP 1/2 and 3/4, a total of 935 lbs of nitrogen will be required.

Assuming adequate payload margins, this total requirement can be launched on AAP-2 if stored in ambient pressure vessels.

The two most likely candidate storage vessels available from Apollo spacecraft are the Block I and Block II SPS helium pressurization tanks. Table 2 indicates a comparison of those tanks for AAP 3/4 requirements only, and for the combined requirements of AAP 1/2 and 3/4. In both cases the Block I tanks yield lower weights for the nitrogen overlay. The total weight of nitrogen and tanks for AAP 3/4 alone is 1362 lbs; for AAP 1/2 and 3/4 the required nitrogen-plus-tank weight is 2111 lbs. Therefore a two-gas atmosphere can be provided for both missions by incurring a weight penalty on AAP-2 of 749 lbs above the N_2 requirement for AAP 3/4 alone.

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Attachments
Tables 1 and 2
References

Copy to
(see next page)

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*Reference 16

Copy to
Messrs. J. H. Disher - NASA/MLD
J. A. Edwards - NASA/MLO
T. E. Hanes - NASA/MLA
C. W. Mathews - NASA/ML
E. J. McLaughlin - NASA/MM
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TABLE 1

Nitrogen Requirements for AAP 1/2 and 3/4

	AAP 1/2 (28 Days)	AAP 3/4 (56 Days)
Workshop Initial Pressurization	136 lbs	136 lbs
Leakage	205 lbs	410 lbs
Airlock Repressurizations for EVA	16 lbs*	32 lbs*
Mission Totals	357 lbs	578 lbs

*Assumes 15 EVA's for AAP 1/2 and 30 for AAP 3/4.

TABLE 2

Nitrogen Tankage Requirements

Candidate Tanks	Block I SPS He	Block II SPS He
Tank Volume	20 ft^3 spherical	20 ft^3 spherical
Operating Pressure	4400 psia	3500 psia
Useful Nitrogen per Tank	326 lbs	269 lbs
Tank Dry Weight	392 lbs	335 lbs
Nitrogen Required		
AAP 1/2 only	578 lbs	578 lbs
AAP 1/2 and 3/4	935 lbs	935 lbs
Number Tanks Required		
AAP 3/4 only	2	3
AAP 1/2 and 3/4	3	4
Required Nitrogen Plus Tank Weight		
AAP 3/4 only	1362 lbs	1583 lbs
AAP 1/2 and 3/4	2111 lbs	2275 lbs

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